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(71) Applicant(s)
Fujitsu Limited
(Incorporated in Japan)
1-1 Kamikodanaka 4-chome, Nakahara-ku, Kawasaki-shi, Kanagawa 211-8588, Japan

(72) Inventor(s)
Behzad Mohebbi

(74) Agent and/or Address for Service
Haseltine Lake & Co
Imperial House, 15-19 Kingsway, LONDON, WC2B 6UD, United Kingdom

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(54) Abstract Title

Diversity transmission means with phase adjustment depending upon a feedback signal supplied to the transmitter by the receiver

(57) In a cellular mobile communications network a transmitter in a base station (1) transmits simultaneously to a receiver in a mobile station (5) a first downlink transmission (DS_{A1}) from a first antenna (2) and a second downlink transmission signal (DS_{A2}) from a second antenna (3), the first and second transmission signals both being derived from the same basic downlink signal which is to be transmitted to the receiver. The receiver in the mobile station (5) generates a feedback signal based on the said first and second downlink transmission signals as received at the receiver without processing those received signals separately from one another. Preferably, the feedback signal is transmission power control (TPC) information sent by the mobile station to the base station for use by the base station to control the power of the downlink transmission signals (DS_{A1}, DS_{A2}). The transmitter adjusts a phase of the second transmission downlink signal relative to that of the first transmission downlink signal in dependence upon the feedback signal.

Such a network can achieve a worthwhile transmit diversity gain without requiring complicated signal processing in the mobile station.

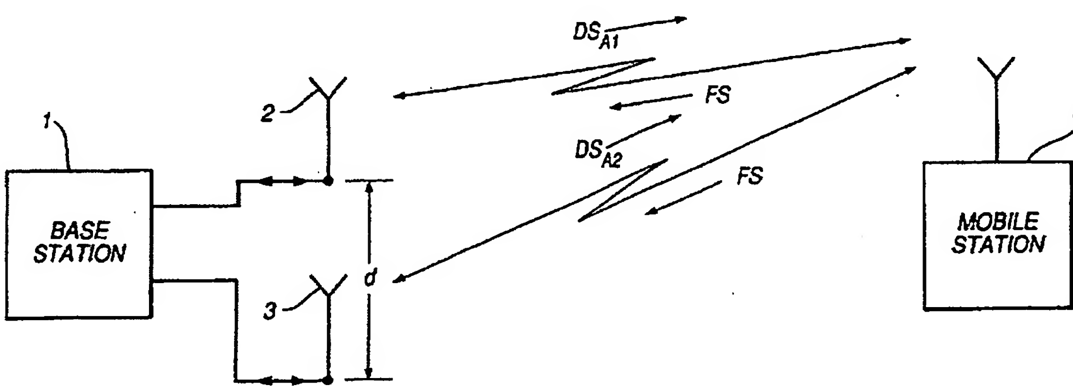

Fig.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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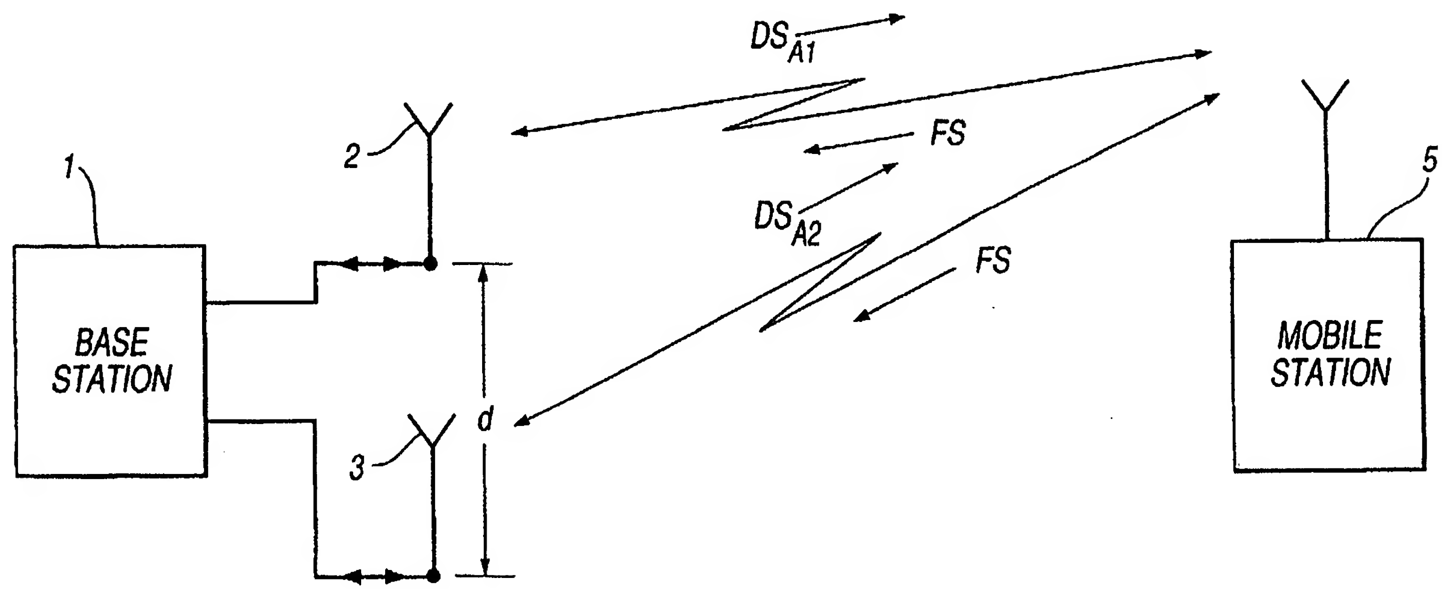

Fig.1

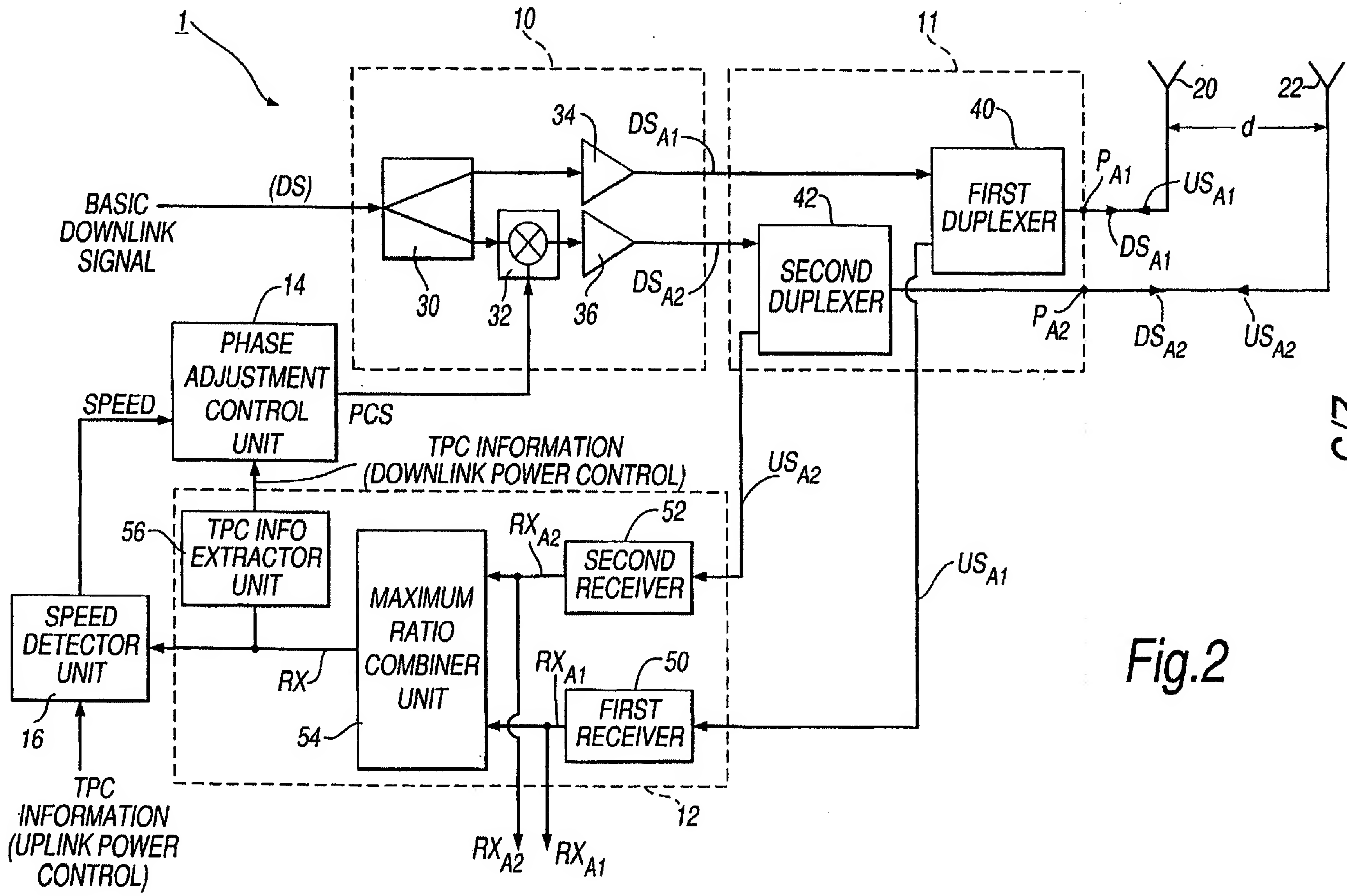
1
10
11
BASIC DOWNLINK SIGNAL
(DS)
30
32
34
36
DS_{A1}
DS_{A2}
40
FIRST DUPLEXER
42
SECOND DUPLEXER
P_{A1}
P_{A2}
US_{A1}
US_{A2}
20
22
d
14
PHASE ADJUSTMENT CONTROL UNIT
SPEED
PCS
TPC INFORMATION (DOWNLINK POWER CONTROL)
56
TPC INFO EXTRACTOR UNIT
MAXIMUM RATIO COMBINER UNIT
54
52
SECOND RECEIVER
50
FIRST RECEIVER
RX_{A2}
RX_{A1}
RX
12
SPEED DETECTOR UNIT
16
TPC INFORMATION (UPLINK POWER CONTROL)

Fig.2

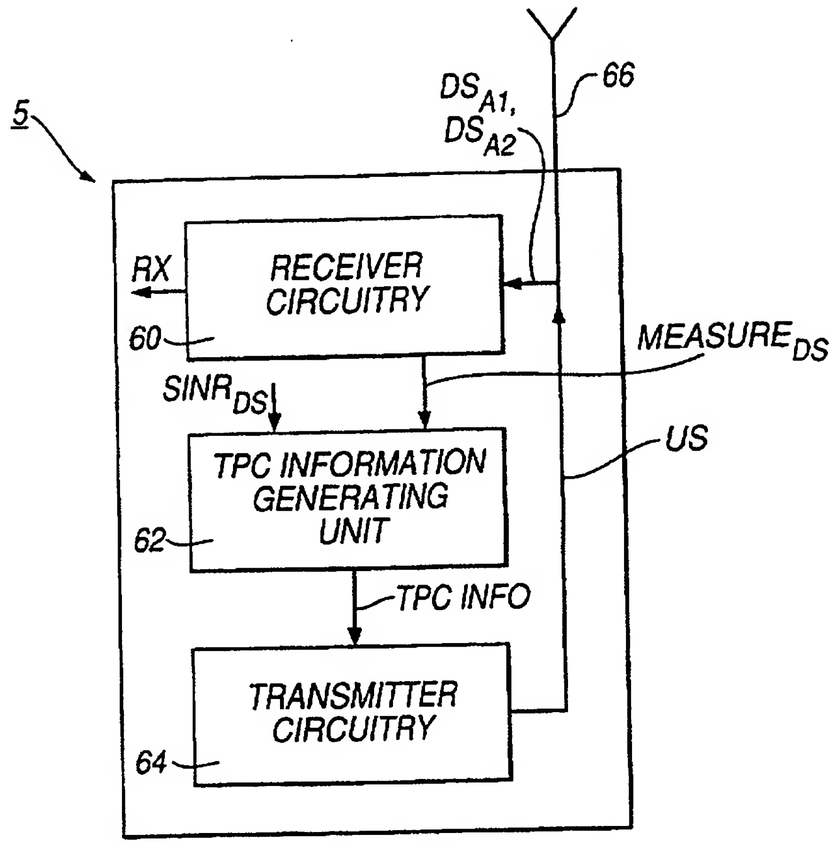
5
66
DS_{A1},
DS_{A2}
RX
RECEIVER CIRCUITRY
60
MEASURE$_{DS}$
$SINR_{DS}$
TPC INFORMATION GENERATING UNIT
62
US
TPC INFO
TRANSMITTER CIRCUITRY
64

Fig.3

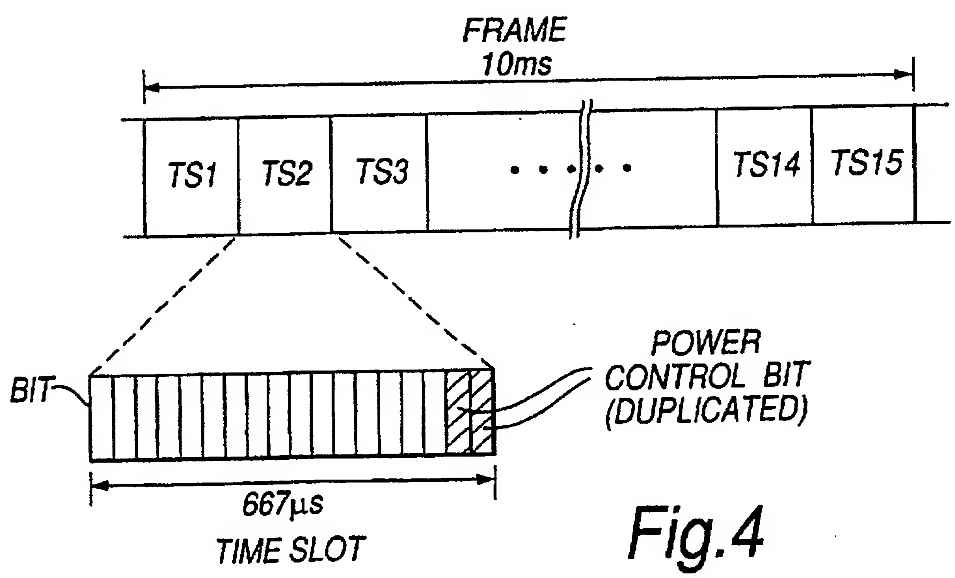
FRAME
10ms
TS1
TS2
TS3
TS14
TS15
BIT
POWER CONTROL BIT (DUPLICATED)
667μs
TIME SLOT

Fig.4

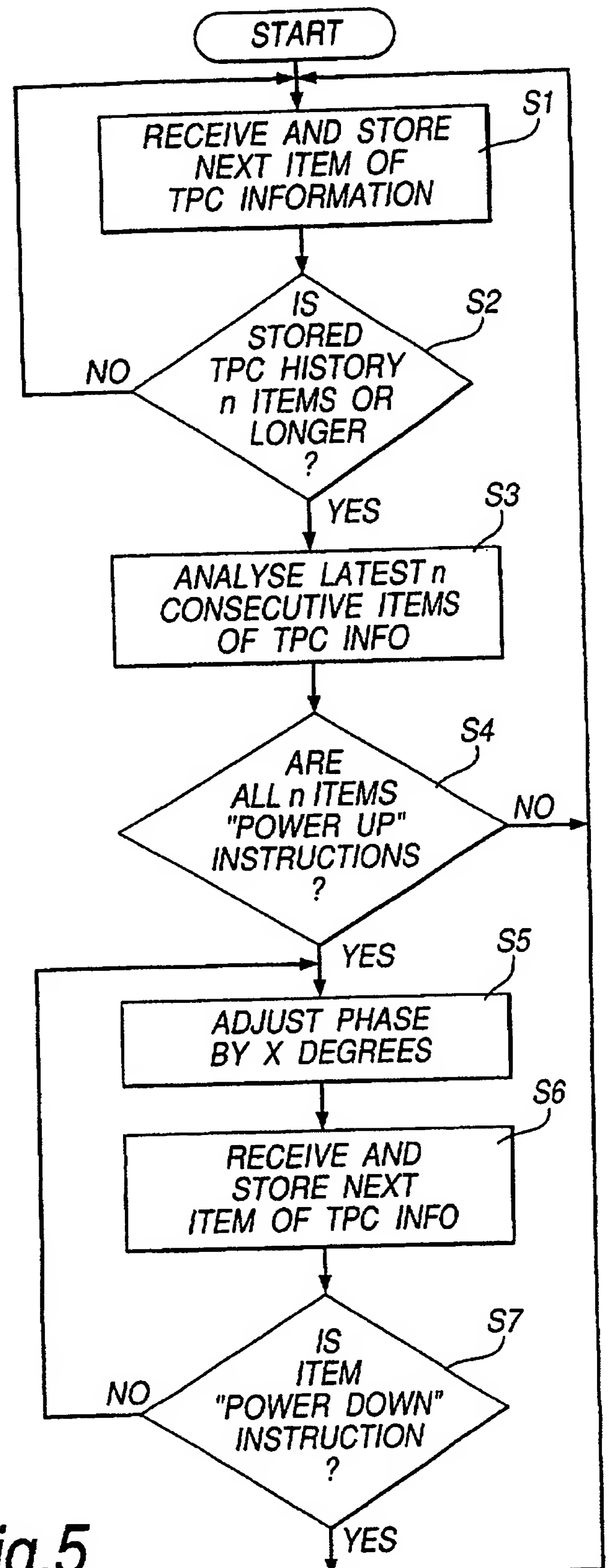
START
RECEIVE AND STORE NEXT ITEM OF TPC INFORMATION
S1
IS STORED TPC HISTORY n ITEMS OR LONGER ?
S2
NO
YES
ANALYSE LATEST n CONSECUTIVE ITEMS OF TPC INFO
S3
ARE ALL n ITEMS "POWER UP" INSTRUCTIONS ?
S4
NO
YES
ADJUST PHASE BY X DEGREES
S5
RECEIVE AND STORE NEXT ITEM OF TPC INFO
S6
IS ITEM "POWER DOWN" INSTRUCTION ?
S7
NO
YES

Fig.5

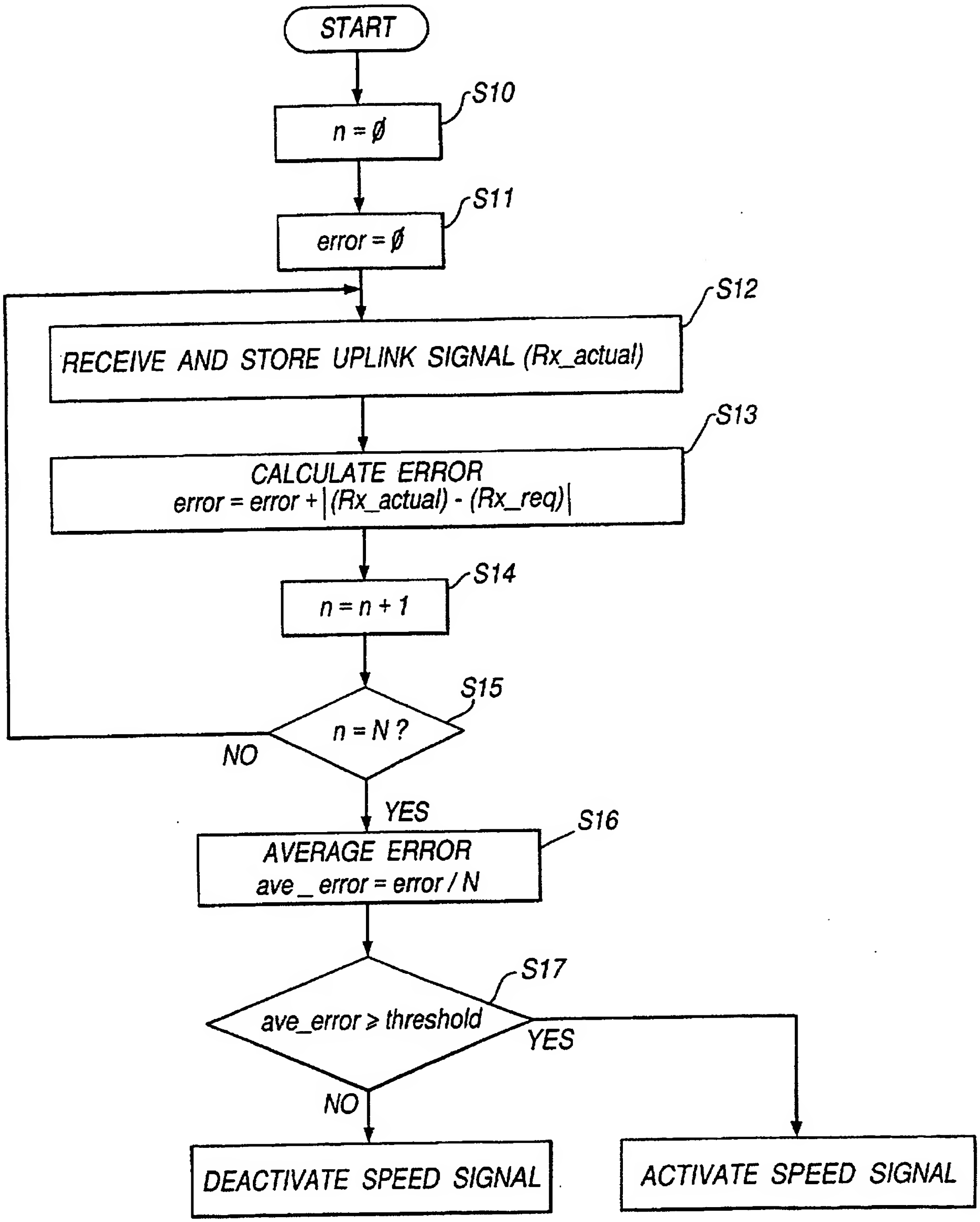
START
S10
n = Ø
S11
error = Ø
S12
RECEIVE AND STORE UPLINK SIGNAL (Rx_actual)
S13
CALCULATE ERROR
error = error + |(Rx_actual) - (Rx_req)|
S14
n = n + 1
S15
n = N ?
NO
YES
S16
AVERAGE ERROR
ave _ error = error / N
S17
ave_error ≥ threshold
YES
NO
DEACTIVATE SPEED SIGNAL
ACTIVATE SPEED SIGNAL

Fig.6

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TRANSMIT DIVERSITY

The present invention relates to transmit diversity. In particular, but not exclusively, the present invention relates to transmit diversity techniques for use in cellular mobile communications networks.

One mobile communications network currently under development by the European Telecommunications Standards Institute (ETSI) is referred to as a UTRA network. UTRA stands for UMTS Terrestrial Radio Access, and UMTS stands for Universal Mobile Telecommunication System (a third generation mobile telecommunication system).

It is expected that in such a UTRA network the capacity in the downlink direction (from a base station to a mobile station) will be more limited than in the uplink direction (from a mobile station to a base station) in view of the types of asymmetric-operation service which will be provided by the network. Such asymmetric-operation services include cell broadcast, wireless Internet and file transfer.

In view of the more severe capacity limitations applying to downlink transmissions, various proposals have been made for using transmit diversity techniques for downlink transmission. Such techniques are presently under investigation in ETSI SMG2-L1 group (SMG2 stands for special mobile group 2 and L1 stands for layer 1) and in 3GPP-TSG-RAN-WG1 group (3GPP stands for third generation partnership project, TSG stands for technical specification group, RAN stands for radio access network, and WG1 working group 1). In these techniques two antennae are provided at a base station for transmitting downlink signals to mobile stations within that base station's cell, the two antennae being spaced apart sufficiently that the fading

characteristics of signals transmitted from the two antennae are uncorrelated in a multi-path fading environment. Most of the techniques use switched diversity, such that only one of the two antennae is selected for transmitting a downlink signal to a particular user (mobile station) at any given time, the selected antenna being switched from time to time to improve the downlink transmission performance. Other proposed techniques transmit the downlink signal for a particular user from both antennae and manipulate the amplitudes and/or phases of the signals transmitted from the two antennae to improve the downlink transmission performance.

Some of the proposed techniques involve the use of a feedback loop in which the mobile station transmits back to the base station some information relating to the downlink signal as received by the mobile station. This information can then be used by the base station to control the transmit diversity, for example the switching from one antenna to the other. However, the provision of such a feedback loop is problematical for several reasons.

Firstly, the speed of response of the feedback loop needs to be high enough to deal with mobile stations that are moving. Many of the existing proposals which use a feedback loop are incapable of providing the speed of response needed to provide useful transmit diversity control for downlink transmissions to a fast-moving mobile station.

Secondly, some of the proposed techniques involve relatively complicated processing activity in the mobile station in order to provide the feedback signals. Such complicated processing increases the power consumption of the mobile station and also increases its cost. Furthermore, complicated processing may be incapable of providing results with

the frequency required for dealing with fast-moving mobile stations.

Accordingly, it is desirable to provide a transmit diversity technique involving a feedback loop which is capable of operating with non-stationary mobile stations and which does not require complicated processing in the mobile stations.

According to a first aspect of the present invention there is provided communications apparatus including a transmitter and a receiver, wherein: the transmitter includes diversity transmission means for transmitting simultaneously to the receiver a first transmission signal from first antenna means and a second transmission signal from second antenna means, the first and second transmission signals both being derived from the same basic signal which is to be transmitted to the receiver, and also includes phase adjustment means for adjusting a phase of the second transmission signal relative to that of the first transmission signal in dependence upon a feedback signal supplied to the transmitter by the receiver; and the receiver includes feedback signal generating means for generating the said feedback signal based on the said first and second transmission signals as received at the receiver without processing those received signals separately from one another.

According to a second aspect of the present invention there is provided a cellular mobile communications network including communications apparatus embodying the aforesaid first aspect of the invention, wherein: the said transmitter is included in a base station of the network; the said receiver is included in a mobile station of the network; the said first and second transmission signals are respectively first and second downlink signals both derived from the same basic downlink signal which is to be transmitted

by the base station to the mobile station; and the said feedback signal is included in an uplink signal transmitted by the mobile station to the base station.

According to a third aspect of the present invention there is provided a base station, for use in a cellular mobile communications network, including: diversity transmission means for transmitting simultaneously to a mobile station of the network a first downlink signal from first antenna means and a second downlink signal from second antenna means, the first and second downlink signals both being derived from the same basic downlink signal which is to be transmitted to the mobile station and both signals embodying identical sequences of symbols; and phase adjustment means for adjusting a phase of the said second downlink signal relative to that of the said first downlink signal in dependence upon a feedback signal supplied to the base station by the mobile station.

According to a fourth aspect of the present invention there is provided a diversity transmission method, wherein: a transmitter transmits simultaneously to a receiver a first transmission signal from first antenna means and a second transmission signal from second antenna means, the first and second transmission signals both being derived from the same basic signal which is to be transmitted to the receiver; the receiver generates a feedback signal based on the first and second transmission signals as received at the receiver without processing those receive signals separately from one another, and supplies the feedback signal to the transmitter; and the transmitter adjusts a phase of the second transmission signal relative to that of the first transmission signal in dependence upon the said feedback signal.

Reference will now be made, by way of example, to

the accompanying drawings, in which:

Figure 1 shows a base station and a mobile station for use in a cellular mobile communications network embodying the present invention;

Figure 2 shows a block diagram of parts of a base station in an embodiment of the present invention;

Figure 3 shows a block diagram of parts of a mobile station in an embodiment of the present invention;

Figure 4 shows an example of the format of transmission power control information transmitted in an embodiment of the present invention;

Figure 5 shows a flowchart for use in explaining a phase rotation algorithm used in an embodiment of the present invention; and

Figure 6 shows one example of the constitution of a speed detector unit in the Figure 2 embodiment.

In Figure 1 a base station 1 has respective first and second antennae 2 and 3 which are spaced apart physically by a distance d. A mobile station 5 is present within a receiving range of the base station 1.

In use of the base station 1, downlink signals intended for reception by the mobile station 5 are transmitted simultaneously from both antennae 2 and 3. The first antenna 2 transmits a first-antenna downlink signal DS_{A1} to the mobile station 5 and the second antenna 3 transmits a second-antenna downlink signal DS_{A2} to the mobile station 5. The spacing d between the two antennae is such that the multipath fading characteristics of the two downlink signals DS_{A1} and DS_{A2} are uncorrelated. The first-antenna and second-antenna downlink signals DS_{A1} and DS_{A2} are each complex signals having inphase (I) and quadrature (Q) components.
To provide transmit diversity, the phase of the second-antenna downlink signal DS_{A2} relative to that of the first-antenna downlink signal DS_{A1} can be varied

from time to time by the base station 1.

Both the downlink signals are derived from a common basic downlink signal which it is desired to transmit to the mobile station 5, and both embody the same sequences of symbols.

The mobile station 5 receives both the first-antenna and second-antenna downlink signals DS_{A1} and DS_{A2} and processes them to recover therefrom the original downlink signal generated in the base station for the mobile station concerned. In addition, the mobile station 5 generates at intervals a feedback signal FS which is transmitted back to the base station 1. The feedback signals FS are generated in dependence upon a measure or measures of one or more predetermined properties of the received downlink signals without processing the two signals separately from one another. In this way, it is not necessary for the mobile station complexity (handset complexity) to be increased to deal with the transmit diversity at the base station 1.

The feedback signals FS are transmitted by the mobile station 5 to the base station 1 which uses the feedback signals to adjust the phase of the second-antenna downlink signal DS_{A2} relative to that of the first-antenna downlink signal DS_{A1}.

In order to facilitate useful operation in environments having fast-moving mobile stations, the or each measure produced in the mobile station 5 must be one that is capable of being produced in a desirably short time window. For example, it is desirable to be able to produce measures (feedback signals) at a frequency of more than 1kHz. In a preferred embodiment of the present invention, the measure adopted for transmit diversity control purposes is downlink transmission power control (TPC) information. Such information is produced at a sufficiently high frequency (e.g. 1.5kHz) to enable it to be applied

usefully to transmit diversity control. In addition, as mobile stations for use in present-generation and third-generation networks are already being designed with downlink TPC information generating functions, the mobile station complexity is not increased, nor is the mobile station operation modified in any way, to implement the transmit diversity. Although this makes downlink TPC information a preferred measure to use for generating the feedback signals, there are many other measures that could be used, including a bit error rate (BER) or frame error rate (FER) or a signal-to-noise-and-interference (SINR) of the received downlink signals. Also, measures of power other than TPC information could also be used.

Incidentally, "downlink TPC information", as used in this specification, means TPC information for downlink power control purposes, i.e. for use in controlling the power of downlink transmissions from the base station to the mobile station. This downlink TPC information is actually transmitted in the uplink direction from the mobile station to the base station. Similarly, "uplink TPC information" means TPC information for uplink power control purposes, i.e. for use in controlling the power of uplink transmissions from the mobile station to the base station. This uplink TPC information is transmitted in the downlink direction from the base station to the mobile station.

A preferred embodiment of the present invention will now be described with reference to Figures 2 to 7. In this embodiment the downlink-signal measure used to generate feedback signals is the downlink TPC information.

Figure 2 shows parts of a base station in the present embodiment. The base station 1 includes a transmitter section 10, a duplexer section 11, a receiver section 12, a phase adjustment control unit

14, and a speed detector unit 16. The base station also has respective first and second antennae 20 and 22.

The transmitter section 10 has a first input for receiving a basic downlink signal DS for transmission to a particular mobile station. The transmitter section also has a further input for receiving a phase control signal PCS from the phase adjustment control unit 14. The transmitter section 10 has respective first and second outputs. The first output delivers a first-antenna downlink signal DS_{A1} for application to the first antenna 20, and the second output delivers a second-antenna downlink signal DS_{A2} for application to the second antenna 22.

The duplexer section 11 has first and second inputs connected respectively to the first and second outputs of the transmitter section 10 for receiving therefrom the first-antenna and second-antenna downlink signals DS_{A1} and DS_{A2}. The duplexer section 11 also has first and second outputs. The first output delivers a first-antenna uplink signal US_{A1} received using the first antenna 20, and the second output delivers a second-antenna uplink signal US_{A2} received using the second antenna 22. The duplexer section 11 also has respective first and second antenna connection ports P_{A1} and P_{A2} connected respectively to the first and second antennae 20 and 22. Each antenna connection port P_{A1} or P_{A2} is a bi-directional port for inputting and outputting radio frequency (RF) signals.

The receiver section 12 has first and second inputs connected respectively to the first and second outputs of the duplexer section 11 for receiving therefrom the first-antenna and second-antenna uplink signals US_{A1} and US_{A2}. Optionally, the receiver section 12 also has receive signal outputs for outputting respective first-antenna and second-antenna receive

signals RX_{A1} and RX_{A2} corresponding respectively to the first and second antennae 20 and 22. The receiver section 12 further has a main receive signal output for delivering a received signal RX based on both the first-antenna and second-antenna uplink signals US_{A1} and US_{A2}, and a TPC output for delivering downlink TPC information derived from those uplink signals.

The speed detector unit 16 has a first input for receiving the received signal RX output by the receiver section 12, and a further input for receiving uplink TPC information generated in the base station for controlling the uplink transmission power of the mobile station. The speed detector unit 16 has an output connected to an input of the phase adjustment control unit 14 for applying a control signal SPEED thereto.

The transmitter section 10 includes a splitter 30, a phase rotator 32, and respective first and second power amplifiers 34 and 36. The splitter 30 receives the basic downlink signal DS intended for transmission to the mobile station and splits it into first and second identical signals S1 and S2. The first signal S1 is applied directly to an input of the first power amplifier 34 which amplifies that signal to produce the first-antenna downlink signal DS_{A1}. The second signal S2 is applied to an input of the phase rotator 32, which also receives the phase control signal PCS generated by the phase adjustment control unit 14. The phase rotator 32 adjusts the phase of the S2 signal to produce a phase-adjusted signal S2'. The phase-adjusted signal S2' is applied to an input of the second power amplifier 36 which amplifies that signal to generate the second-antenna downlink signal DS_{A2}.

The duplexer section 11 contains respective first and second duplexers 40 and 42. The first duplexer 40 receives the first-antenna downlink signal DS_{A1} at an input thereof and passes it to the antenna connection

port P_{A1} for the first antenna 20. The second duplexer 42 receives the second-antenna downlink signal DS_{A2} at an input thereof and passes it to the second antenna connection port P_{A2} for the second antenna 20.

In this way, in use of the Figure 2 base station, the first-antenna and second-antenna downlink signals DS_{A1} and DS_{A2} are both derived from the basic downlink signal DS intended for the mobile station concerned, and the phase of the second-antenna downlink signal DS_{A2} relative to the first-antenna downlink signal DS_{A1} is controlled in dependence upon the phase control signal PCS.

In the receiving direction, the first and second duplexers 40 and 42 receive first-antenna and second-antenna uplink signals US_{A1} and US_{A2} from the antennae 20 and 21 respectively and pass them to respective outputs thereof. The receiver section 12 includes first and second receivers 50 and 52. The first receiver 50 receives the first-antenna uplink signal US_{A1} from the first duplexer 40, and the second receiver 52 receives the second-antenna uplink signal US_{A2} from the second duplexer 42. The first receiver 50 carries out conventional receive processing on the first-antenna uplink signal US_{A1} to extract therefrom the first-antenna receive signal RX_{A1}. The second receiver 52 does the same for the second antenna and produces the second-antenna receive signal RX_{A2}. The two receive signals RX_{A1} and RX_{A2} are applied to respective inputs of a maximum ratio combiner (MRC) unit 54 which in known manner combines the two receive signals to produce a combined receive signal RX based on the combined first-antenna and second-antenna uplink signals US_{A1} and US_{A2}.

The receiver section 12 further comprises a TPC extractor unit 56 which receives the combined receive signal RX output by the MRC unit 54 and extracts therefrom any downlink TPC information contained in the

received signal RX. The format and purpose of the downlink TPC information in the uplink signals received from the mobile station will be explained later.

The phase adjustment control unit 14 receives the TPC information from the TPC extractor unit 56, as well as the control signal SPEED produced by the speed detector unit 16, and processes the received information and the received signals in accordance with a predetermined phase adjustment control algorithm (one example which is described later with reference to Figure 5) to produce the phase control signal PCS.

Examples of the constitution and operation of the optional speed detector unit 16 will be given later with reference to Figure 6.

As shown in Figure 3, the mobile station 5 includes receiver circuitry 60, a TPC information generating unit 62, and transmitter circuitry 64. The receiver circuitry 60 and transmitter circuitry 64 are connected, for example via a duplexer (not shown), to an antenna 66 of the mobile station.

The receiver circuitry 60 receives the first-antenna and second-antenna downlink signals DS_{A1} and DS_{A2} transmitted by the base station. The receiver circuitry 60 carries out conventional receive processing on the received first-antenna and second-antenna downlink signals DS_{A1} and DS_{A2} and passes a receive signal RX, based on the received downlink signals, to further circuitry (not shown) of the mobile station. The receiver circuitry 60 is unaware of the transmit diversity employed at the base station and does not distinguish between, or separately process, the two downlink signals DS_{A1} and DS_{A2} received thereby. The receiver circuitry 60 also produces a downlink-signal measure $MEASURE_{DS}$ of one or more predetermined properties of the downlink signals DS_{A1} and DS_{A2} as received by the mobile station. In this embodiment the

downlink-signal measure $MEASURE_{DS}$ is a measure of signal-to-noise-and-interference ratio (SINR) of the combined downlink signals DS_{A1} and DS_{A2} as received, but in other embodiments other properties of the combined downlink signals could be measured such as received power, bit error rate, frame error rate, etc. In this embodiment the measure is produced in each timeslot of the downlink signals.

The downlink-signal measure $MEASURE_{DS}$ is received by the TPC information generating unit 62. The TPC information generating unit 62 also receives an intended or target received SINR $SINR_{DS}$ for downlink signals. This intended SINR $SINR_{DS}$ represents an SINR level required by the mobile station for the downlink signals sent by the base station to be received satisfactorily.

The TPC information generating unit 62 compares the received SINR measure $MEASURE_{DS}$ produced by the receiver circuitry 60 with the intended received SINR $SINR_{DS}$ and generates TPC information in dependence upon the result of the comparison.

One possible format of the TPC information, proposed for the UTRA network, is shown in Figure 4. As shown in Figure 4, uplink signal transmissions from the mobile station to the base station are formatted as a succession of frames, each frame being of duration 10ms, for example. Each frame is in turn divided up into a number of individual timeslots. For example, as shown, a frame may be made up of fifteen individual timeslots TS1 to TS15, each of duration 667μs. In this example, each individual timeslot contains TPC information in the last two bits of the timeslot, the TPC information within each timeslot consisting of the same power control bit sent twice in succession. The same power control bit is sent twice in succession to enable error checking of the TPC information included

in the received uplink signal to be carried out at the base station.

The power control bit can have a value "1", representing a "power up" instruction to the base station, or "0" representing a "power down" instruction to the base station. Upon receiving such a power up instruction, the base station increases its downlink transmission power to the mobile station concerned by a predetermined amount, for example 1dB. Upon receiving such a power down instruction, on the other hand, the base station decreases its downlink transmission power to the mobile station by a predetermined amount, for example 1dB.

The TPC information generating unit 62 operates in each timeslot of the received downlink signals from the base station to produce a power control bit, providing either the power up or power down instruction, for inclusion in the uplink signal in the next-available uplink-signal timeslot so as to enable the base station to adjust its downlink transmission power for the next downlink-signal timeslot allocated to the mobile station concerned.

For example, when the result of the comparison performed by the TPC information generating unit 62 is that the received SINR measure $MEASURE_{DS}$ has fallen below the intended received SINR $SINR_{DS}$, the power up instruction is given (power control bit set to "1"). On the other hand, when the received SINR measure $MEASURE_{DS}$ exceeds the intended received SINR $SINR_{DS}$, the TPC information generating unit 62 generates the power down instruction (power control bit set to "0").

The power down/power up instruction (power control bit) is applied to the transmitter circuitry 64 of the mobile station, which incorporates the power control bit into the uplink signal for the next-available uplink-signal timeslot. Accordingly, the TPC

information is forwarded to the base station for use thereby to set the downlink transmission power to use for the mobile station.

It will be seen that the frequency of the TPC information (power control bit) in the uplink signals is relatively high (for example 1.5kHz in the case of a timeslot duration of 667μs and 1 power control bit per timeslot), making the control for the downlink transmission power fast enough to operate satisfactorily with mobile stations moving at speeds of up to 100km/h, for example.

In the present embodiment, as well as using the TPC information for downlink transmission power control purposes, the base station also uses the TPC information for transmit diversity control purposes. Referring back to Figure 2, the TPC information included in the uplink signals received by the base station is extracted by the TPC extractor unit 56 and supplied to the phase adjustment control unit 14. One example of the operation of the phase adjustment control unit 14 will now be given with reference to Figure 5.

In a step S1 the next item of TPC information (next power control bit) in the receive signal RX derived from the first-antenna and second-antenna uplink signals US_{A1} and US_{A2} is received by the phase adjustment control unit 14 and stored therein. Step S1 is repeated until it is determined in step S2 that the stored TPC history has at least n items of TPC information. Here, n is a preselected integer greater than or equal to 2 (discussed later). When at least n items are available, processing proceeds to step S3 in which the latest n consecutive items of TPC information are analysed. If, in step S4, it is determined that the latest n consecutive items of TPC information that have been received and stored by the unit are not all power up instructions, processing returns to step S1.

In step S4, if all n items are power up instructions from the mobile station processing proceeds to step S5. In step S5 it is determined that the phase of the second-antenna downlink signal, relative to the phase of the first-antenna downlink signal, should be adjusted by a predetermined amount X degrees. For example X may be 90 or 180°. The phase control signal PCS is adjusted to reflect the desired new phase of the second-antenna downlink signal DS_{A2}, and the phase control signal is applied to the phase rotator 32 in the transmitter section 10 to bring about the required phase change.

Then, in step S6 the next item of TPC information following the phase adjustment is received and stored. In step S7 it is checked whether or not the item concerned is a power down instruction. If it is not a power down instruction, processing returns to step S5 and steps S5 and S6 are repeated until such time as a power down instruction is received, the phase of the second-antenna downlink signal DS_{A2} being adjusted in steps X until that time.

When, in step S7, the power down instruction is detected, processing returns to step S1 at which the next item of TPC information is received and stored.

The phase adjustment control process shown by way of example in Figure 5 enables the phase of the second-antenna downlink signal DS_{A2} to be rotated for slow-moving mobile stations such that the overall combined downlink signal received at the mobile station is maintained at a sufficiently-high level to permit satisfactory reception at the mobile station, even when one of the individual antenna downlink signals is experiencing significant fast fading.

It will be appreciated that other phase adjustment control processes than the one shown in Figure 5 can be used. For example, processes can be used in which the

step size X of the phase adjustment is variable in dependence upon the TPC history. Similarly, the step direction may be determined in dependence upon the TPC history. Also, in steps S5 and S6, a step in phase may only be taken if two or more consecutive power up instructions are received, rather than just one, to give a longer response time to the last step in phase taken.

The decision to adjust the phase in the Figure 5 process is made only after receiving n consecutive power up instructions because in this embodiment the downlink transmission power control loop can only provide either a power up or a power down instruction in any particular timeslot. Thus, when the downlink power level does not require adjustment a series of alternate power up and power down instructions will be received at the base station. By setting $n \geq 2$, phase adjustments can be avoided in this situation.

Much more sophisticated phase adjustment control processes can be employed in the unit 14. For example, the unit could include a maximum-entropy (auto-regressive) filter that could predict the future phase adjustments based on the TPC information and/or on the received uplink signals themselves (for example the phase and amplitude of those received uplink signals). Further information on such auto-regressive filters can be found in "Digital Signal Processing - A Practical Approach", Emmanuel C Ifeachor & Barrie W Jervis, Addison-Wesley Publishing Company, ISBN 0201 54413X, USA, 1993, pp. 578-9.

The speed detector unit 16 included in the Figure 2 base station will now be described with reference to Figure 6. The speed detector unit 16 is provided to detect when the mobile station is moving at more than a preselected speed. Such detection is useful because, in the case of very fast-moving mobile stations, the TPC information received via the uplink signals will be

too great for the TPC information in the uplink signals to be used reliably for phase adjustment purposes. In such a case, using the TPC information received in the uplink signals for phase adjustment purposes could be counterproductive.

It is not readily possible from the information available to it for the base station to determine whether or not the downlink power control loop is operating sufficiently well. However, it is possible for the base station to determine whether the corresponding uplink power control loop is operating properly. This uplink power control loop operates in basically the same way as the downlink power control loop, in that the base station monitors the received SINR of the uplink signals received from the mobile stations and compares the received SINR with an intended received SINR needed for satisfactory operation of the receiver section 12. TPC information reflecting the results of the comparison is then included in the downlink transmission signal sent to the mobile station in each timeslot.

Figure 6 shows a flowchart of a possible speed detection process which can be carried out in the speed detector unit 16 to detect when a mobile station is moving at more than a preselected speed based on the TPC information used for uplink power control.

In a first step S10 a count value n is set to 0 and in step S11 an error value *error* is set to 0 to initialise the speed detector unit 16.

In each timeslot, the speed detector unit 16 takes the main (combined) receive signal RX produced by the receiver section 12 and determines the actual receive power *Rx_actual* of that signal (step S12). In step S13 the error value *error* is increased by the absolute difference between the actual received power *Rx_actual* of the receive signal RX and a required received power

Rx_req for the uplink signals from the mobile station concerned. This required received power *Rx_req* is set equal to the actual receive power Rx for the immediately-preceding timeslot plus a fixed amount (e.g. 1dB) if the last power control instruction issued by the base station to the mobile station was a "power up" instruction, and is set to less than the immediately-preceding actual receive power *Rx_actual* by a predetermined amount (e.g. 1dB) if the last power control instruction was a "power down" instruction.

Thus, the effect of step S13 is to increase the error value if the outcome of the last power control instruction was not as intended.

In step S13 the count value n is incremented and, in step S15 it is determined whether the count value has reached a predetermined final value N. If not, the steps S12 to S14 are repeated until the final value is reached.

When the final value is reached, processing continues at step S16 in which an average value ave_error of the error value over the last N timeslots is calculated. The final value N may be chosen, for example, such that the mobile station is allowed to travel through a distance of approximately 40 λ over the period of the N timeslots, where λ is the transmission wavelength of the uplink signals transmitted to the base station from the mobile station. For a mobile station travelling at 100km/h and transmitting at a frequency of 2GHz with timeslots of duration of 667μs, the final value N should be set at approximately 320.

In step S17 the average error value *ave_error* calculated in step S16 is compared with an error threshold value *threshold*. If the average value of the error is greater than or equal to the threshold value, this indicates that the mobile is moving at more than a

preselected speed, and a control signal SPEED applied to the phase adjustment control unit 14 is activated. If, on the other hand, the average value of the error is less than the threshold value in step S17, the SPEED control signal is deactivated.

When the phase adjustment control unit 14 receives the active SPEED signal the phase of the second-antenna downlink signal DS_{A2} relative to the first-antenna downlink signal DS_{A1} may be fixed until such time as the SPEED signal is deactivated. Alternatively, phase hopping can be used when the SPEED signal is active. In such phase hopping the phase of the second-antenna downlink signal is varied in a predetermined manner in successive timeslots by the phase adjustment control unit 14 or even varied randomly.

Many other speed detection methods can be used in embodiments of the present invention. For example, a speed detection method based on detecting a Doppler frequency shift of the uplink carrier signal can be used.

Many different structures and formats of TPC information can be used in embodiments of the present invention. For example, any number of TPC bits can be included in each timeslot, and the bits need not be duplicated as in Figure 4. The bits can be placed at any position in the timeslot, either spaced out or consecutively. Each TPC bit may not individually define a power change. For example, the power might only be changed by a fixed amount (e.g. 1dB) when, say, four consecutive identical commands have been received. Also, in other networks it is envisaged that the TPC information will include a "stay the same" instruction, specifying that the power is to be left unchanged, as well as "power up" and "power down" instructions. The TPC information could also provide explicit "go to power level X" commands in other networks.

Although the present invention has been described above in relation to a UTRA network, it will be appreciated that it can also be applied to other networks in which it is desired to provide transmit diversity based on phase adjustment. These networks could be, or could be adapted from, other CDMA networks such as a wideband CDMA (W-CDMA) network or an IS95 network. These networks could also be, or be adapted from, other mobile communications networks not using the CDMA, for example networks using one or more of the following multiple-access techniques: time-division multiple access (TDMA), wavelength-division multiple access (WDMA), frequency-division multiple access (FDMA) and space-division multiple access (SDMA).

Also, although embodiments of the present invention have been described as having distinct "units" such as the phase adjustment control unit, those skilled in the arts appreciate that a microprocessor or a digital signal processor (DSP) may be used in practice to implement some or all of the functions of the base station and/or mobile station in embodiments of the present invention.

In the Figure 2 embodiment, the first-antenna and second-antenna downlink signals DS_{A1} and DS_{A2} after amplification have the same power levels. However, it is not necessary for these two signals to have the same power levels. There may be instances where it is desirable, for example due to the physical arrangement of the two antennae, for the downlink signal of one antenna to be transmitted at a higher power than that of the other antenna.

The relative amplitudes of the first-antenna and second-antenna downlink signals could also be adjusted in dependence on the feedback signals (TPC information) from the mobile station, if desired to further improve the diversity gain.

More than two antennae could be provided for transmitting respective downlink signals to the mobile station, the relative phases of the signals being adjustable in dependence upon the feedback signals from the mobile station.

The or each antenna could be an antenna array or a single antenna.

Also, although in the Figure 2 embodiment the phase adjustment of the second-antenna downlink signal relative to the first-antenna downlink signal is carried out in the RF domain, it will be appreciated that this phase adjustment could be carried out in the baseband or in an intermediate frequency (IF) band intermediate between the baseband and the RF domain.

It is also possible to use a transmit diversity technique embodying the present invention to provide transmit diversity for uplink signals transmitted from a mobile station to a base station. In this case, the mobile station would require two antennae to transmit its uplink signals to the base station and would use feedback signals, such as uplink TPC information, received from the base station to control the relative phases of the uplink signals transmitted from the two antennae. The antennae would need to be spaced apart by at least $\lambda/2$, where λ is the wavelength of the uplink signals transmitted. For example, in a network having a frequency of 2GHz, $\lambda/2$ would be approximately 7cm, which is readily achievable even in compact mobile stations, and certainly practical in mobile terminals such as notebook-size or laptop computers.

CLAIMS:

1. Communications apparatus including a transmitter and a receiver, wherein:

the transmitter includes diversity transmission means for transmitting simultaneously to the receiver a first transmission signal from first antenna means and a second transmission signal from second antenna means, the first and second transmission signals both being derived from the same basic signal which is to be transmitted to the receiver, and also includes phase adjustment means for adjusting a phase of the second transmission signal relative to that of the first transmission signal in dependence upon a feedback signal supplied to the transmitter by the receiver; and

the receiver includes feedback signal generating means for generating the said feedback signal based on the said first and second transmission signals as received at the receiver without processing those received signals separately from one another.

2. A cellular mobile communications network including communications apparatus as claimed in claim 1, wherein:

the said transmitter is included in a base station of the network;

the said receiver is included in a mobile station of the network;

the said first and second transmission signals are respectively first and second downlink signals both derived from the same basic downlink signal which is to be transmitted by the base station to the mobile station; and

the said feedback signal is included in an uplink signal transmitted by the mobile station to the base station.

3. A network as claimed in claim 2, having downlink power control means for controlling a

transmission power of one or each of said first and second downlink signals in dependence upon transmission power control (TPC) information supplied to the base station by the mobile station, the said feedback signal being derived from such TPC information.

4. A network as claimed in claim 3, wherein the said feedback signal is provided directly by such TPC information.

5. A network as claimed in claim 3 or 4, wherein the said base station includes phase adjustment control means for controlling operation of the said phase adjustment means in dependence upon a history of such TPC information.

6. A network as claimed in claim 5, wherein the said phase adjustment control means are operable to cause the said phase adjustment means to effect such a phase adjustment when at least n consecutive items of said TPC information indicate that the said transmission power should be increased, where n is a predetermined integer greater than or equal to 2.

7. A network as claimed in claim 6, wherein the said phase adjustment control means are operable to cause the said phase adjustment means to effect a further such phase adjustment in response to each subsequent item of said TPC information indicating that the said transmission power should be increased, until an item of said TPC information is received that does not indicate that the said transmission power should be increased.

8. A network as claimed in any one of claims 3 to 7, wherein an item of such TPC information is included in the said uplink signal in every timeslot thereof.

9. A network as claimed in any one of claims 3 to 8, wherein a new item of said TPC information is calculated for the first and second downlink signals

received in every timeslot of the downlink signals.

10. A network as claimed in any one of claims 3, 4, 8 and 9, wherein the said base station includes phase adjustment control means, having a maximum-entropy filter, for predicting future such phase adjustments to be performed by the said phase adjustment means in dependence upon the said TPC information and/or upon one or more predetermined characteristics of the said uplink signal as received by the base station.

11. A network as claimed in any one of claims 2 to 10, wherein the base station further includes speed detector means for detecting when the mobile station is moving at more than a preselected speed, and phase adjustment inhibiting means operable to modify or inhibit operation of the phase adjustment means when it is determined that the mobile station is moving at more than the said preselected speed.

12. A network as claimed in claim 11, wherein the base station further includes phase hopping means operable, when it is determined that the mobile station is moving at more than the said preselected speed, to cause the said phase adjustment means to effect phase adjustments according to a predetermined hopping pattern or according to a random hopping pattern.

13. A network as claimed in claim 11 or 12, having uplink power control means for controlling a transmission power of the said uplink signal transmitted by the mobile station in dependence upon transmission power control (TPC) information supplied by the base station to the mobile station, and the said speed detector means are operable to determine that the mobile station is moving at more than the said preselected speed when the uplink transmission power is not being controlled effectively by the said uplink power control means.

14. A base station, for use in a cellular mobile communications network, including:

diversity transmission means for transmitting simultaneously to a mobile station of the network a first downlink signal from first antenna means and a second downlink signal from second antenna means, the first and second downlink signals both being derived from the same basic downlink signal which is to be transmitted to the mobile station and both signals embodying identical sequences of symbols; and

phase adjustment means for adjusting a phase of the said second downlink signal relative to that of the said first downlink signal in dependence upon a feedback signal supplied to the base station by the mobile station.

15. A base station as claimed in claim 14, for use in a cellular mobile communications network having downlink power control means for controlling a transmission power of such downlink signals in dependence upon transmission power control (TPC) information supplied to the base station by the mobile station, wherein the said feedback signal is derived from such TPC information.

16. A base station as claimed in claim 15, wherein the said feedback signal is provided directly by such TPC information.

17. A diversity transmission method, wherein:

a transmitter transmits simultaneously to a receiver a first transmission signal from first antenna means and a second transmission signal from second antenna means, the first and second transmission signals both being derived from the same basic signal which is to be transmitted to the receiver;

the receiver generates a feedback signal based on the first and second transmission signals as received

at the receiver without processing those receive signals separately from one another, and supplies the feedback signal to the transmitter; and

the transmitter adjusts a phase of the second transmission signal relative to that of the first transmission signal in dependence upon the said feedback signal.

18. Communications apparatus substantially as hereinbefore described with reference to the accompanying drawings.

19. A cellular mobile communications network substantially as hereinbefore described with reference to the accompanying drawings.

20. A base station for use in a cellular mobile communications network substantially as hereinbefore described with reference to the accompanying drawings.

21. A diversity transmission method substantially as hereinbefore described with reference to the accompanying drawings.

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Application No: GB 9919492.0
Claims searched: 1-17

Examiner: Hannah Bryant
Date of search: 23 February 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H4L (LDDRCP, LDDSF, LDDSX)

Int Cl (Ed.7): H04B 7/02, 7/04, 7/06, 7/08, 7/10, 7/12

Other: Online: WPI EPODOC JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US5689439 (WEERACKODY)	
A	US4748682 (FUKAE)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.